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## Original article

# Digital assessment of preliminary impression accuracy for edentulous jaws: Comparisons of 3-dimensional surfaces between study and working casts



Takashi Matsuda DDS<sup>a</sup>, Takaharu Goto DDS, PhD<sup>a,\*</sup>,  
 Kosuke Kurahashi DDS<sup>a</sup>, Toshiya Kashiwabara DDS, PhD<sup>a</sup>,  
 Megumi Watanabe DDS, PhD<sup>a</sup>, Yoritoki Tomotake DDS, PhD<sup>b</sup>,  
 Kan Nagao DDS, PhD<sup>a</sup>, Tetsuo Ichikawa DDS, PhD<sup>a</sup>

<sup>a</sup>Department of Oral and Maxillofacial Prosthodontics, Institute of Biomedical Sciences, Tokushima University Graduate School, Japan

<sup>b</sup>Oral Implant Center, Tokushima University Hospital, Japan

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## ABSTRACT

**Purpose:** The aim of this study was to compare 3-dimensional surfaces of study and working casts for edentulous jaws and to evaluate the accuracy of preliminary impressions with a view to the future application of digital dentistry for edentulous jaws.

**Methods:** Forty edentulous volunteers were serially recruited. Nine dentists took preliminary and final impressions in a routine clinical work-up. The study and working casts were digitized using a dental 3-dimensional scanner. The two surface images were superimposed through a least-square algorithm using imaging software and compared qualitatively. Furthermore, the surface of each jaw was divided into 6 sections, and the difference between the 2 images was quantitatively evaluated.

**Results:** Overall inspection showed that the difference around residual ridges was small and that around borders were large. The mean differences in the upper and lower jaws were 0.26 mm and 0.45 mm, respectively. The maximum values of the differences showed that the upward change mainly occurred in the anterior residual ridge, and the downward change mainly in the posterior border seal, and the labial and buccal vestibules, whereas every border of final impression was shortened in the lower jaw. The accuracy in all areas except the border, which forms the foundation, was estimated to be less than 0.25 mm.

**Conclusion:** Using digital technology, we here showed the overall and sectional accuracy of the preliminary impression for edentulous jaws. In our clinic, preliminary impressions have been made using an alginate material while ensuring that the requisite impression area was covered.

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\* Corresponding author at: Department of Oral and Maxillofacial Prosthodontics, Institute of Biomedical Sciences, Tokushima University Graduate School, 3-18-15 Kuramoto-cho, Tokushima 770-8504, Japan. Tel.: +81 88 633 7347; fax: +81 88 633 7461.

E-mail address: [tak510@tokushima-u.ac.jp](mailto:tak510@tokushima-u.ac.jp) (T. Goto).

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## 1. Introduction

Impression taking is the first process in the fabrication of complete dentures and is important for achieving retention, support, and stability of complete dentures [1]. Conventionally, after the preliminary impression is taken with a ready-made tray and the study cast is fabricated, a final impression is made with a customized tray. The final impression can also be made by bite registration or using a trial wax denture as a “bite-seating impression”.

Although impression accuracy has often been discussed for crown and bridge fabrication, there is little information on the accuracy of impressions for edentulous jaws, except in terms of the influence of various impression methods on the outline of the denture foundation [2], as the mucosa freely changes under various types of compressions while taking an impression. The quality of complete dentures fabricated using two different techniques, i.e., traditional impression involving taking a preliminary impression using a stock tray and a final impression using a customized tray, vs. and a single impression taken with a stock tray, has been compared in terms of patient satisfaction [3,4]. However, the differences in the 3-dimensional surfaces between impressions taken with these two approaches have been not investigated.

Recently, the development of a scanner has made it possible to take a tooth impression for crown and bridge fabrication, and it will soon be possible to take a direct digital impression of edentulous jaws. This scanner also allows easy measurement of 3-dimensional surfaces and quantitative evaluation.

In this study, the shapes of study and working casts were quantitatively evaluated and compared using a 3-dimensional scanner and specialized software, in order to clarify the accuracy of the preliminary impression, with a view to future taking of direct digital impressions for edentulous jaws.

## 2. Materials and methods

This research was conducted with the approval of the Ethics Committee of the Tokushima University Hospital (No. 1475).

Forty edentulous volunteers (35 upper jaw cases and 30 lower jaw cases; mean age:  $75 \pm 7$  y) were investigated as subjects in this study. All of these individuals visited the Prosthodontic Department of the Tokushima University Hospital for fabrication of new complete dentures from April, 2013 to March, 2015, and for whom informed consent for participation in this study was obtained from both the patients and attending dentists. Individuals with symptoms of stomatognathic disorder, ulcers, and mucosal abnormalities were excluded. The 9 dentists attending to the 40 edentulous volunteers had clinical experience from 1 to 31 years (mean age:  $39 \pm 11$  y), and three of them were board certified prosthodontists.

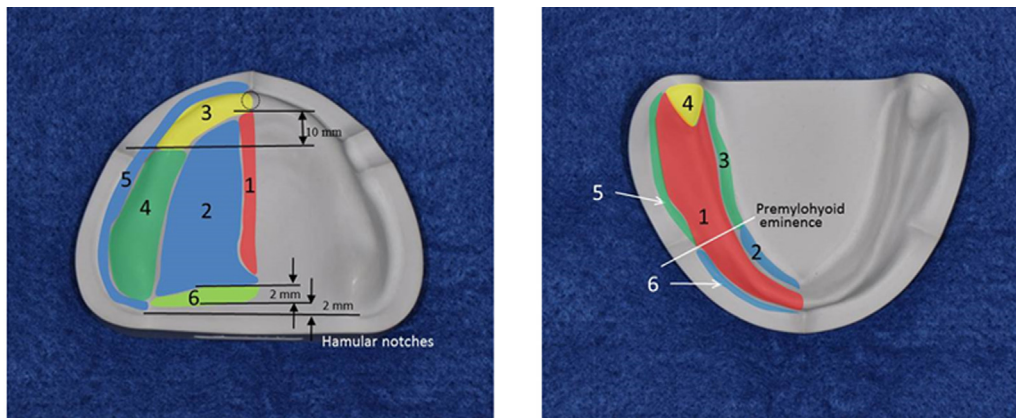
Preliminary impressions were taken using a ready-made tray and an alginate impression material (ALGINoplast EM normal, Heraeus Kulzer Japan Co., Ltd., Tokyo, Japan). Dentists were required to use requisite anatomical landmarks for complete denture fabrication: the ready-made tray could be

modified slightly using wax, according to the individual dentist's judgment, and as little pressure as possible was applied while taking the impression. A study cast was fabricated according to the manufacturer's instructions, using a dental plaster (Zostone, Shimomura Gypsum Co., Ltd., Saitama, Japan). This study cast was used to make a customized acrylic tray in a conventional manner, with blackout and relief in the necessary parts and without a spacer. The final impression was made using this tray and a silicone material (Examixfine Regular, GC Co., Tokyo, Japan) after muscle trimming. A working cast was fabricated in a same way as for the study cast.

The study and working casts were digitized using a dental 3-dimensional scanner (Dental Wings 7Series, Dental Wings Inc., Montreal, Canada) so that all of the impression surface was covered. This device provides five-axis processing and a nominal resolution of  $\pm 15 \mu\text{m}$ . The error value of the 3-dimensional scanner was determined to be within  $\pm 15 \mu\text{m}$  by the manufacturer through the repeated measurement of the shape and superimposition. This error value was confirmed using a similar approach in our experiment. The accuracy of this scanner was thus enough to evaluate the impression accuracy of the edentulous ridge. Three-dimensional scanning was done in a constant environment: at a temperature of  $(25 \pm 3) ^\circ\text{C}$ , humidity of  $(60 \pm 10) \%$ , and  $(1014 \pm 10)$  hPa atmosphere. The scanner was calibrated with the aluminum calibration plate ( $125 \text{ mm} \times 10 \text{ mm} \times 100 \text{ mm}$ , Dental Wings Inc., Montreal, Canada) according to the manufacturer's instruction. Parts other than the impression surface in the 3-dimensional images were trimmed and edited on the monitor by a single operator and a single inspector. The two surface images of the study and working casts were superimposed through a least-square algorithm using imaging software (Gom Inspect V7 SR2, GOM mbH, Braunschweig, Germany), such that the surface image of the working cast approximately matched that of the study cast with the least-square error, and were examined qualitatively on the screen.

Furthermore, the surface of each jaw was divided into six sections according to the functional significance reported by Boucher [5,6], and the differences between the two images were quantitatively evaluated for each of these areas. The six sections in each jaw were defined as shown in Fig. 1. The boundary of the sections was determined through inflection points by agreement between two examiners. A downward direction, which indicates that the surface of the working cast was settled relative to that of the study cast, was defined as “plus”; conversely, the upward direction, which indicates that the surface of working cast was lifted relative to that of the study cast, was defined as “minus”. The maximum values of the difference in upward and downward directions (minimum value for the downward direction), and the distribution ratio of three categories (less than the absolute difference of 0.25 mm, between 0.25 and 0.5 mm, and more than 0.5 mm) were quantitatively examined for each section.

The shape of residual ridge in each jaw was classified according to the treatment difficulty indices developed by the Japan Prosthodontic Society [7], and the differences between the two images were also evaluated for classification of residual ridge shapes.



- 1. Median palatine raphe
- 2. Secondary retentive stress-bearing areas of palate
- 3. Anterior residual ridge
- 4. Posterior residual ridge
- 5. Labial and buccal vestibules
- 6. Posterior palatal seal

- 1. Residual ridge
- 2. Anterior alveolingual sulcus
- 3. Posterior alveolingual sulcus
- 4. Retromolar pad
- 5. Buccal vestibule
- 6. Labial vestibule

Fig. 1 – The six sections that were compared in the 3-dimensional surfaces between the study and master casts.

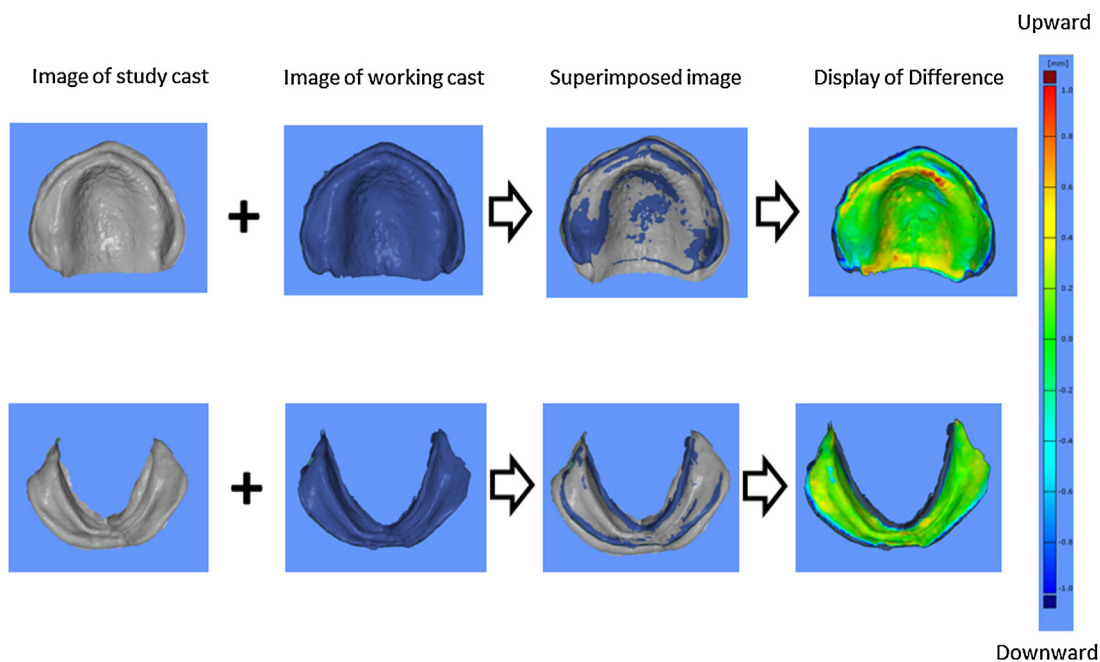


Fig. 2 – Superimposition of images of the study and working casts.

2.1. Statistical analysis

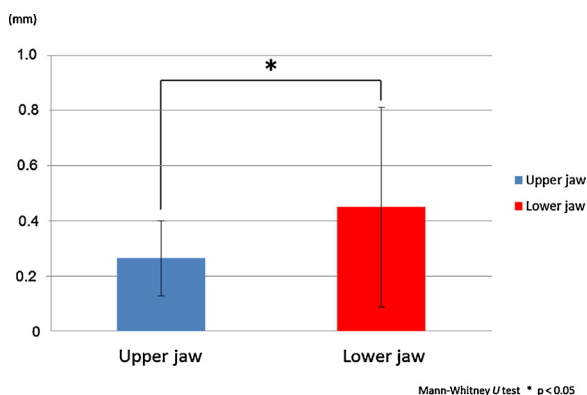
The Mann–Whitney U-test and Bonferroni’s post hoc test was used for statistical analysis, and was conducted using SPSS® version 22.0 (SPSS Co., Chicago, IL, USA). Significance was accepted at  $p < 0.05$ .

3. Results

Fig. 2 shows typical images superimposed with the 3-dimensional images of the study and working casts. Green,

red, and blue colors refer to the coincidence between the two images, the lower part of the working cast relative to the study cast, and the upper part relative to the study cast, respectively.

Overall inspection showed that the difference between the cases was the smallest in the median palatine raphe; the difference increased in the order: posterior residual ridge, anterior residual ridge, secondary retentive and stress-bearing areas of the palate, posterior palatal seal, and labial and buccal vestibules. Green to yellow colors were largely found around the posterior residual ridge, as the primary stress-bearing area, and yellow to red colors were found around the anterior residual ridge.



**Fig. 3 – Mean differences between the study and working models in each jaw.**

In the upper jaw, yellow to orange colors were largely found around the rugae as secondary retentive stress-bearing areas of the palate, and green to blue colors were mainly found around the median palatine raphe, as the relief area. Yellow to red colors were found around the buccal vestibules.

In the lower jaw, the differences between the scans were low around the residual ridge; conversely the differences around the border seals were large. Green to yellow and green to orange colors were often found around the buccal shelf, as the primary stress-bearing area, and the residual ridge, as the secondary stress-bearing area, respectively. Blue color was mainly present around the retromolar pad, as the border seal area. Yellow to red colors were largely found around the alveolingual sulcus and the buccal vestibules.

Quantitatively, the mean differences of the upper and lower jaws were 0.26 mm and 0.45 mm, respectively; that of the lower jaw was thus significantly larger (Fig. 3). Figs. 4 and 5 show the differences in the six sections of each jaw in terms of the maximum and actual values of difference, and distribution ratio of the three difference categories: less than 0.25 mm, between 0.25 and 0.5 mm, and more than 0.5 mm. Comparing the maximum values in the downward and upward direction, the location of the working cast relative to that of the study cast can be estimated. Judging from the maximum values in the upper jaw, upward changes were often found in the anterior residual ridge, while downward changes were seen in the posterior border seal and labial and buccal vestibules. The changes in the maximum values in the upward and downward directions were equal when compared to those in the lower jaw. The distribution ratios suggested that the >0.5 mm category was found significantly more often in the buccal vestibule and posterior border seal, and the <0.25 mm category was more often applicable in other sections.

Judging from the maximum values in the lower jaw, every border in the final impression was reduced. The distribution ratios suggested that the differences in the residual ridge and retromolar pad were small; conversely, these were larger in the labial vestibule and alveolingual sulcus. The distribution ratios in the lower jaw was more evenly spread compared to those in the upper jaw. The >0.5 mm category was seldom found in the residual ridge and retromolar pad, and was frequently present in the alveolingual sulcus and buccal

vestibules, while the opposite was true for the <0.25 mm category.

No significant relationship was found between years of clinical experience of the practitioner and the mean difference between the casts in each jaw. Residual ridges were classified into 4 types in vertical and buccolingual dimensions, as shown in Table 1. Most cases were categorized as Level I (high and U-shaped) and Level II (moderate and between U- and V-shaped). No significant relationship was found between residual ridge types and the mean difference between the casts.

#### 4. Discussion

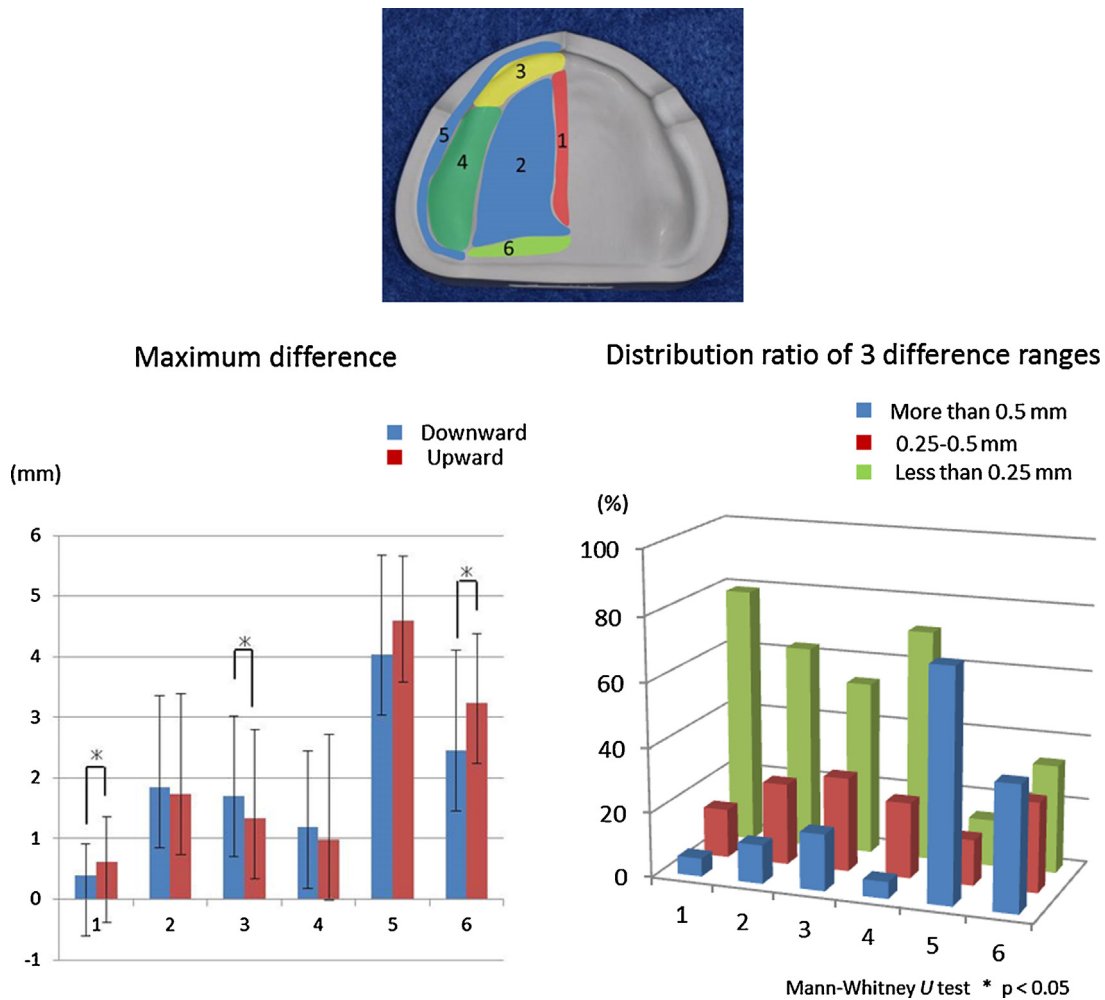
Recent advances in computer and sensor technologies have allowed technological innovations in the field of dentistry, which is termed “digital dentistry”. These innovations have led to the wider commercial availability of intraoral scanners, and the accuracy of impressions for crowns and bridges using this technology has been reported [8–14].

It has also been reported that the use of digital impressions, in which the edentulous jaw is directly measured using a digital apparatus, is currently being investigated [15]. Although Nokubi et al. [16] and Nagaoka et al. [17] evaluated the 3-dimensional morphologies of die casts using digital technology, the measurement capacity of the technology used at that time was much lower than those of current technology.

The target for taking an impression of an edentulous jaw is the mucosa, which has high displacement properties, and it is difficult to determine the denture border and to select the degree of impression pressure, making it difficult to evaluate the true values of an impression. Digital impression of edentulous jaws is expected to be developed soon, but the accuracy and quality of such impressions remain unclear. During the process of taking the final impressions using custom trays, the custom tray is manually adapted to the residual ridge as much as possible. In practice, this clinical procedure is the same approach as the best-fit algorithm used in this study, which entails a numerical superimposition of 2 images through a least-square algorithm. We believe it will be possible to predict the standard accuracy of a preliminary impression for edentulous jaws by comparing the 3-dimensional surfaces between study and working casts, although quantitative values need to be evaluated.

The degree of coincidence between 2 impressions was analyzed in each of the 6 sections into which each jaw was divided, according to the report by Boucher, which represent acceptable functional and anatomical criteria. The results of our superimposition study suggested that the degree of coincidence was high, whereas the degree of coincidence at the border area was low. In taking a preliminary impression with alginate impression material, we have attempted to take the impression in such a way as to include all the anatomical landmarks, rather than to determine the denture border. In taking a final impression using the customized tray, the border is set by border molding, termed “muscle trimming,” as there a large difference was found in this region. It has been reported that the border in a compound impression of upper jaws is





**Fig. 4 – Differences between the upper study and working casts. Maximum difference and distribution ratio of three difference ranges in the six sections compared.**

similar to that in an alginate impression, whereas the border in a compound impression of lower jaws is longer than that in an alginate impression [18]. This study showed the opposite, particularly for the lower jaw, in which the border in the final impression was shorter than that in the preliminary impression. The difference in these findings may be because the preliminary impressions made using alginate impression material in our clinic ensured that the requisite impression area was covered.

The mean difference for the upper jaw was 0.26 mm, but the difference in all areas except the border, which forms the foundation of the upper jaw, should be less than 0.25 mm. There was a large difference at the posterior section of the palate, which is associated with denture retention through the border seal. The location of the soft palate during the impression may affect this difference. The mean difference in the lower jaw was 0.45 mm. The maximum values and distribution ratio of differences in the lower jaws were larger than those in upper jaws. This may be because the residual ridge and palate in the upper jaw involves more flat areas, whereas the residual ridge in the lower jaws involve more sloped areas and the denture border is longer. However, the

differences in all areas except the border should be the same as that in the upper jaw.

The residual ridge shape and clinical experience of the practitioner did not have a marked effect on the difference in values between study and working casts. If these factors influenced both casts equally, their influence might not have been detected in this study. In the criteria of patient selection, the condition of patient visits had priority over the dentist selection. As a result, the 9 dentists who had clinical experience from 1 to 31 years were selected with a wide range of ages and clinical experiences. Although it is reported that the amount of tooth reduction and operation time depend on clinical experience of the practitioner with respect to the abutment tooth preparation [19], the result of this study, in which no relationship between the clinical experience of practitioners and difference of two casts was found, may be characterized as the impression of edentulous mucosa. However, considering the relative numbers of cases and practitioners, the evaluation on the influence of clinical experience of practitioners may not be always sufficient. Further discussion is needed with more case number and standardization of practitioner's experience or skills.

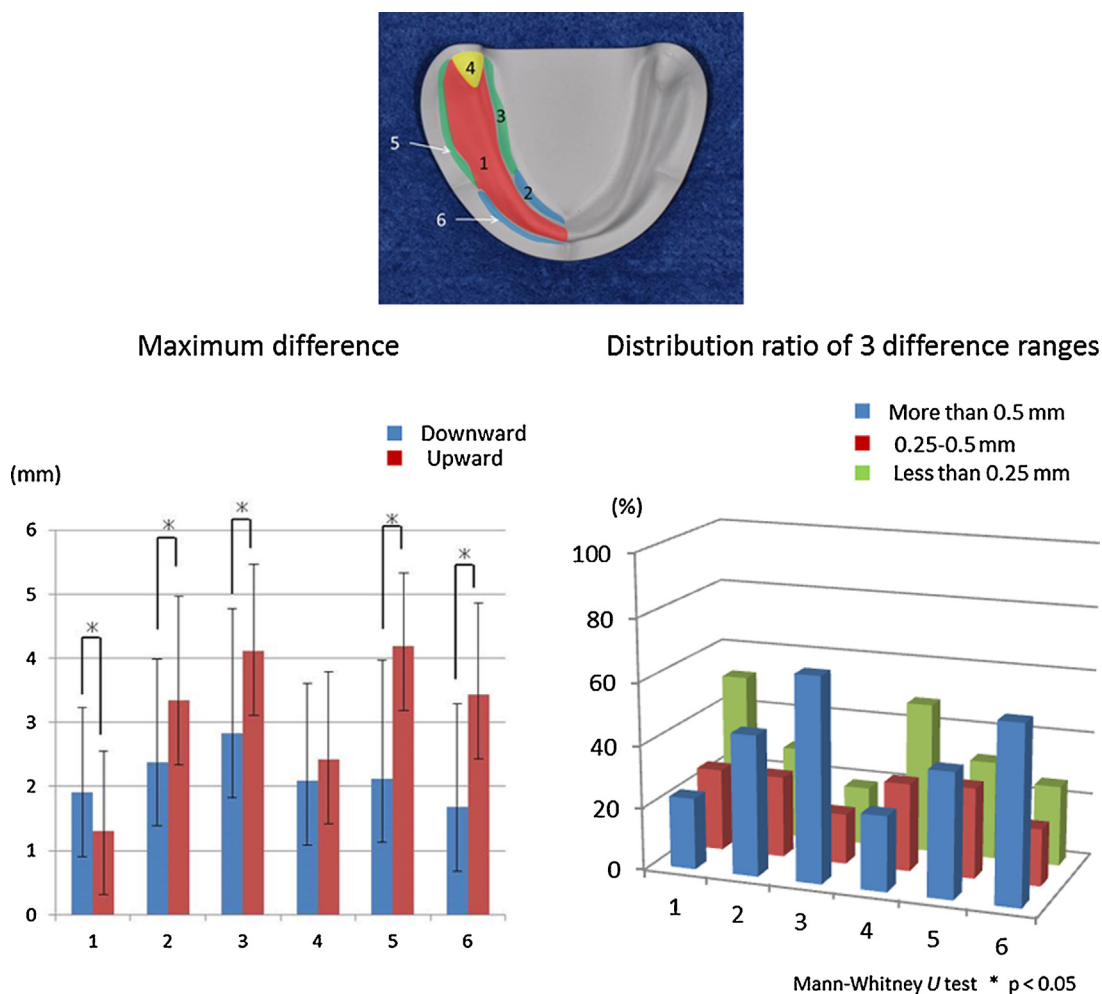


Fig. 5 – Differences between the lower study and working casts. Maximum difference and distribution ratio of three difference ranges in the six sections compared.

Table 1 – Classification of residual ridge shapes and the mean differences between the study and working models.				
	Classification of residual ridge shapes (vertical dimension)			
	Level I	Level II	Level III	Level IV
Maxilla (n = 35)	14 0.25 ± 0.08 mm	20 0.28 ± 0.16 mm	1 0.21 mm	0 –
Mandible (n = 30)	4 0.20 ± 0.03 mm	17 0.52 ± 0.43 mm	0 –	9 0.43 ± 0.22 mm
	Classification of residual ridge shapes (buccolingual dimension)			
	Level I	Level II	Level III	Level IV
Maxilla (n = 35)	13 0.27 ± 0.10 mm	21 0.26 ± 0.16 mm	1 0.25 mm	0 –
Mandible (n = 30)	7 0.46 ± 0.46 mm	19 0.39 ± 0.35 mm	3 0.88 ± 0.02 mm	1 0.19 mm
Upper row: matched number; lower row: difference (mean ± SD).				

### 5. Conclusion

This study investigated the overall and sectional accuracy of preliminary impressions of edentulous jaws using digital

technology. The accuracy of the preliminary impression in all areas except the border area, which forms the foundation on the mucosa, was estimated to be less than 0.25 mm in the upper jaw. In the lower jaws, the accuracy of all areas other than the border was the same. The differences in the denture

border in every section were characterized and preliminary impression using an alginate material was made in our clinic, ensuring that the requisite impression area was covered.

In order for digital direct impressions of edentulous jaws to become practically implemented in future, the accuracy of the new procedure will have to be compared with the conventional procedure. The quantitative differences indicated in this study will be significant for validating the accuracy of complete denture fabrications. Patients and clinicians' condition, including edentulous alveolar ridges, will be categorized and digital assessment of edentulous jaws will be established through the quantitative difference of more clinical cases in future research.

### Conflict of interest

The authors have no conflicts of interest to disclose.

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